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Frequency Generator (Wobbler) to 4GHz

The following article describes a frequency generator with a wobble function for the frequency range from 10 MHz to 4 GHz. The output is approximately +10dBm (10 mW) with a ripple of less than ±1.5 dB over the whole range. It is split into two overlapping ranges. Automatic switching between the two frequency ranges is not absolutely necessary for use in amateur radio and was therefore not included in this design on cost grounds. This also applies to automatic level correction.

1. The Design

The frequency generator/wobbler for up to 4 GHz is a useful aid in measurement and calibration work in the amateur radio field. The technical requirements for the design have been restricted to the absolutely necessary. The block diagram (Fig. 2) shows the functional blocks used at a glance, together with their interaction. The core of the circuit is a YIG oscillator. The maximum tuning range of the module used here lies between 1.6 and 4 GHz. The lower frequency range, between 10MHz and 1.8GHz, is covered using a mixer. This has an associated oscillator, a low pass filter and an amplifier. In both frequency ranges, the output is approximately +10dBm, with a ripple of less than ±1.5dB. Better values can not be obtained without a regulated output amplifier, but this was deliberately discounted with for the reasons explained above.

The wobbler is controlled using a micro controller. This sets YIG oscillator according to the frequency range, and generates the saw tooth tuning voltage required for the wobble. A two line by 16 character liquid crystal display is used to display the current mean frequency and the span. A 10dB directional coupler is inserted at the radio frequency output of the YIG oscillator. This additional output is for measurement purposes (e.g. frequency counters for calibration) and if applicable for the connecting up of a PLL control circuit for narrow band applications. This is, however, optional and is not covered in this article.

2. The YIG Oscillator

The great advantage of YIG oscillators is obvious: a YIG oscillator can be electronically tuned over a very wide frequency range, with a very linear relationship between the tuning voltage (and / or current) and the frequency. The response shown in Fig. 3 shows the frequency

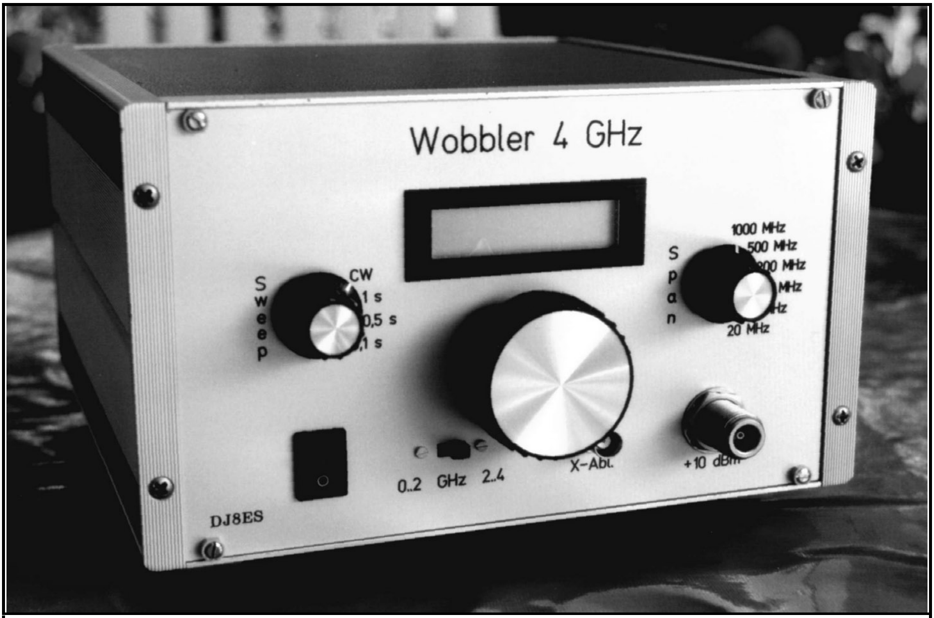

Fig 1: Frequency generator (wobbler) to 4GHz

response of the YIG oscillator in the prototype over a range from 1.6 to 4 GHz.

Just a brief note on the theory behind a YIG oscillator: the abbreviation "YIG" stands for Yttrium Iron Garnet. This is a synthetic crystalline ferrite material, consisting of yttrium and iron (Y3Fe6O16). If such a crystal is surrounded by a magnetic field and in addition radio frequency energy is fed in through a magnetic loop, the element begins to resonate in the radio frequency range. The frequency of resonance is directly proportional to the strength of the magnetic field.

For the practical construction of a YIG oscillator, the magnetic field is generated through an electromagnet. The frequency of resonance is determined by the current

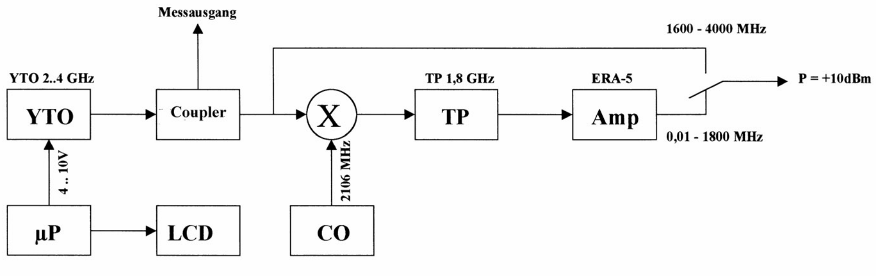

Fig 2: Block diagram of frequency generator.

Frequency	Input
1600	4,09
1700	4,32
1800	4,55
1900	4,79
2000	5,00
2100	5,23
2200	5,46
2300	5,69
2400	5,93
2500	6,16
2600	6,39
2700	6,62
2800	6,85
2900	7,08
3000	7,31
3100	7,53
3200	7,77
3300	8,00
3400	8,23
3500	8,46
3600	8,68
3700	8,92
3800	9,14
3900	9,38
4000	9,62

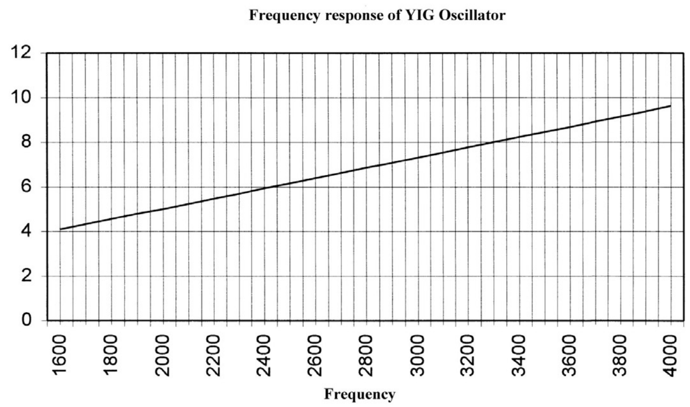

Fig 3: Frequency response of YIG oscillator.

in the magnet coil, and displays linear behaviour. The coils are responsible for the relatively high weight of YIG oscillators. YIG oscillators are available covering the frequency range between 0.5 and 50GHz, in segments. The tuning range usually stretches over one or more octaves. Equipment of this type, in the range of interest for amateur radio between 2 and 18GHz, can be obtained at reasonable prices in surplus stores.

The YIG oscillator used here originates from the HP141T HP spectrum analyser (radio frequency assembly HP8355) and has the following operational data:

- Operating voltage +20 V / 70 mA
-10 V / 7 mA
- Frequency range 1.6 - 4 GHz
- Output 25 mW ±1 dB
- Coil current 50 - 120 mA

The frequency is set using a micro

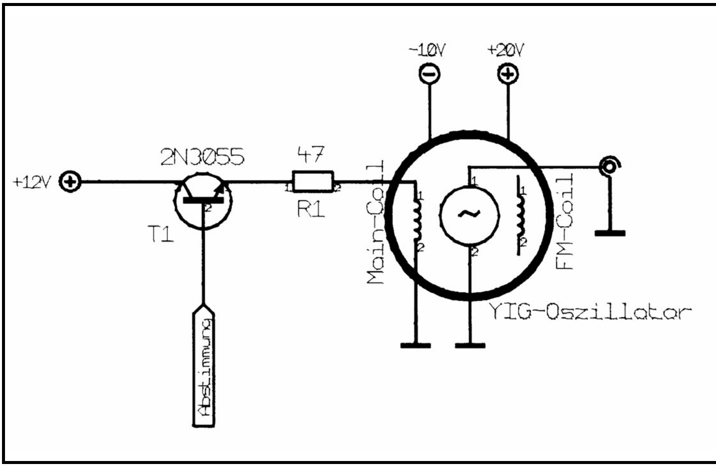

Fig 4: The driver for the YIG oscillator.

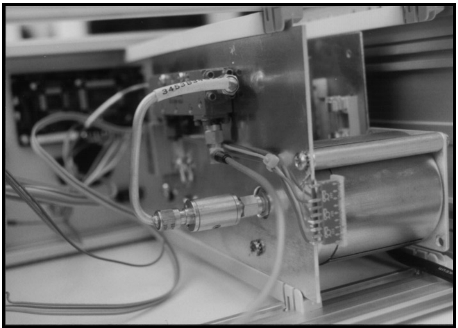

Fig 5: Picture of YIG oscillator.

controller with an integrated D/A converter. Since this can not generate the relatively high current required for the tuning coil (main coil), the transistor circuit with a 2N3055, acts as a driver (Fig. 4). It is important that both the transistor and the subsequent series resistance (47Ω) should be thermally stable. Therefore the 2N3055 is mounted on a cooling surface of generous dimensions. A 25 W type was selected for the 47Ω resistor, which was mounted directly on the mounting plate (base plate).

A 3dB attenuator is fitted directly to the output socket of the YIG oscillator with SMA connections (Fig. 5). This isolates the oscillator from the subsequent circuits. The output, including all losses in the attenuator, the directional coupler, the change over relay and the cable, is almost exactly 10mW.

3. Mixer With Oscillator, Low Pass Filter and Amplifier

3.1. Mixer assembly

For the lower frequency range up to 1.8GHz, the output frequency of the YIG oscillator must be mixed down. The mixer used is an ADE-42MH from Mini Circuits, which is operating in the specified frequency range. In this SMD module the LO and RF ports are specified for the frequency range 5 to 4,200MHz and the intermediate frequency port for 5 to 3,500MHz.

The mixed signal is fed through a 21 pole low pass filter using stripline technology. This suppresses both the image frequency and the signal from the local oscillator at 2,106MHz. Fig. 7 shows the very good frequency response of the low pass filter. Next comes a single stage amplifier using an ERA-1 MMIC which provides a high degree of amplification of approximately 19dB over a wide frequency range. The output level of the mixer assembly is approximately +10dBm (10 mW).

3.1.1. Assembly tips for the mixer module

A double sided copper coated circuit board made from epoxy material with dimensions 53.5 mm. x 146 mm, was

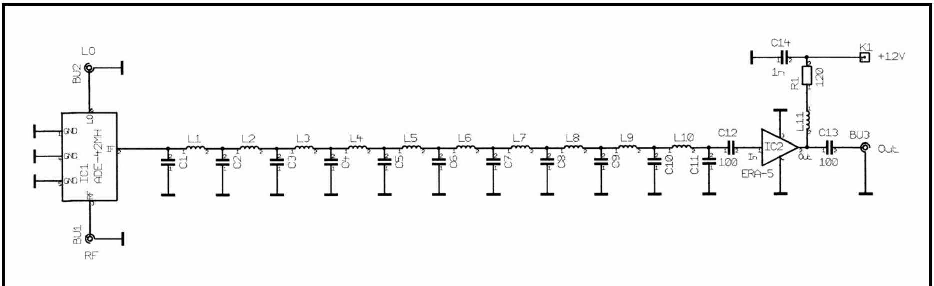

Fig 6: Circuit of mixer with oscillator and low pass filter.

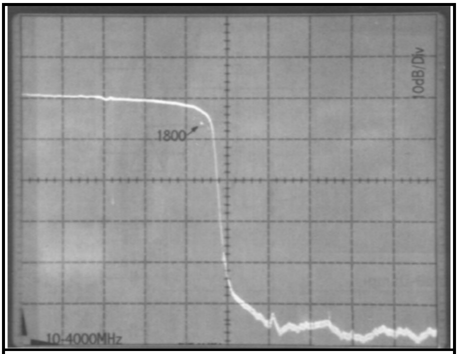

Fig 7: Frequency response of 21 pole filter.

designed for the mixer assembly. First the printed circuit board, still without the components, is soldered into a suitable standard tinplate housing (55 mm x 148 mm x 30 mm). Then the ADE-42MH ring mixer, ERA-5 MMIC and the two 100pF coupling capacitors are soldered in on the copper side. The 120Ω resistor and the 1nF blocking capacitor are soldered in on the component side.

The L11 choke consists of 2 turns wound onto a 2mm former being one lead of the 120Ω resistor. The position of the choke is thus at a distance of approximately 1mm above the printed circuit board.

The supply voltage (+12V) is fed through a feedthrough capacitor (1nF, solderable) in the housing wall. At this supply voltage, the current consumption of the circuit is approximately 60mA. Three SMA connectors are used for radio frequency connections, input (LO and RF) and / or output.

3.1.2. Component list for mixer assembly

IC1	ADE-42MH, ring mixer (Mini-Circuits)
IC2	ERA-5, MMIC (Mini-Circuits)
L1-L10	Stripline, printed
L11	2 turns on 2mm - see text
C1-C11	Capacitor, printed
R1	120Ω / 0.6 W, RM 10 mm
C12,C13	100pF, SMD 0805
C14	1nF, EGPU, RM 2.5 mm
1 x	DJ8ES 053 PCB
1 x	Tinplate housing, 55 mm x 148 mm x 30 mm
1 x	1nF, feedthrough, solderable
3 x	SMA flanged socket

3.2. Oscillator for 2,106MHz

A tried and tested design from Michael Kuhne (DB6NT) acts as a local oscillator. The circuit (Fig. 10) has been slightly modified from the original (oscillator for transverter for the 13cms band).

The quartz oscillator runs at 117.0MHz using a U310 FET. This signal is fed through various frequency multiplier stages to reach the desired frequency of 2,106MHz. A tripler (BFR93A) to 351MHz, a further tripler (BFG93A) to

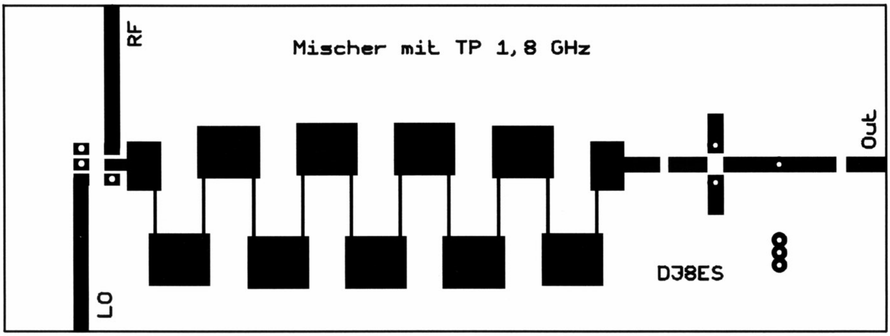

Fig 8: Printed circuit board for mixer DJ8ES-053.

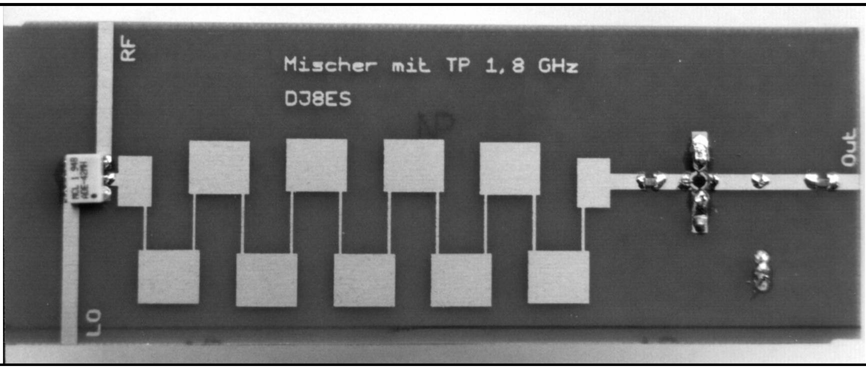

Fig 9: Photograph of the prototype mixer.

1,053MHz and a frequency doubler (BFG93A) to 2,106MHz. The output level here is approximately 2mW.

3.2.1. Assembly tips for local oscillator equipment

The oscillator for 2,106MHz is built on a double sided copper coated epoxy printed circuit board with the dimensions 34 mm x 53.5 mm. The printed circuit board is soldered into a suitable tinplate housing (37 mm x 55 mm x 30 mm).

The DJ8ES 054 printed circuit board is assembled with the mainly SMD component on the track side (Fig. 13). Only the wired components such as the U310 FET, the 117.0MHz crystal and the filters, are inserted in the usual way from components side (fully coated side, Fig. 14). The component drawings show all the details with regard to the position of the components, etc.

The supply voltage (+12V) is fed through a feedthrough capacitor (1nF, solderable). An SMA socket acts as the output for the radio frequency.

3.2.2. Components list for local oscillator

T1	U310, FET
T2	BFR93A, SMD transistor
T3,T4	BFG93A, SMD transistor
IC1	78L09, SMD voltage regulator
Q1	Crystal 117.0MHz, HC-18U, Series resonance 7th overtone
L1	BV5061, 0,1µH, Neosid
L2	5HW-35045A-365, helix filter
L3	5HW-100090A-1010, helix

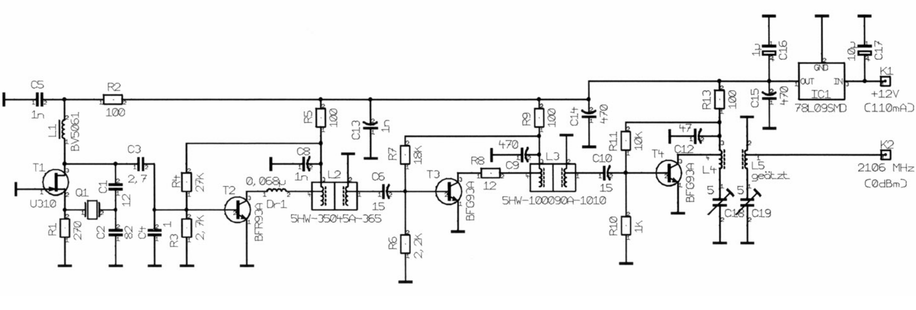

Fig 10: Circuit diagram of 2106MHz oscillator.

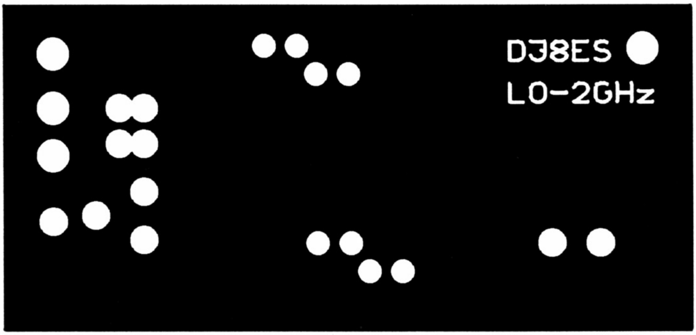

Fig 11: Oscillator printed circuit board, ground plane side.

	filter
L4,L5	Stripline filter, printed
C18,C19	Trimmer 5pF, green, Sky
1 x	DJ8ES 054 PCB
1 x	Tinplate housing, 37 mm x 55 mm x 30 mm
1 x	1nF, solderable, feedthrough
1 x	SMA flanged socket

all remaining components in SMD format 1206 or 0805:

1 x	12Ω
4 x	100Ω
1 x	270Ω
1 x	1kΩ
1 x	2.2kΩ
1 x	2.7kΩ
1 x	10kΩ
1 x	18kΩ
1 x	27kΩ
1 x	2.7pF
1 x	12pF
2 x	15pF
1 x	47pF
1 x	82pF
3 x	40pF
3 x	1nF
1 x	1µF, tantalum
1 x	10µF, tantalum

3.2.3. Putting oscillator assembly into operation

After a final visual check of the fully assembled oscillator assembly for placement errors or solder breaks, it can be put into operation for the first time. The output is determined using a power meter suitable for this frequency range. The maximum current consumption at +12V is 110mA. However, this value is not reached until setup is complete.

There must be + 9 V at the voltage regulator output (IC1). The voltage drop through resistor R2 should be approximately 0.7V. The crystal oscillator can be tuned, the core of the oscillator coil L1 is slowly rotated while the voltage

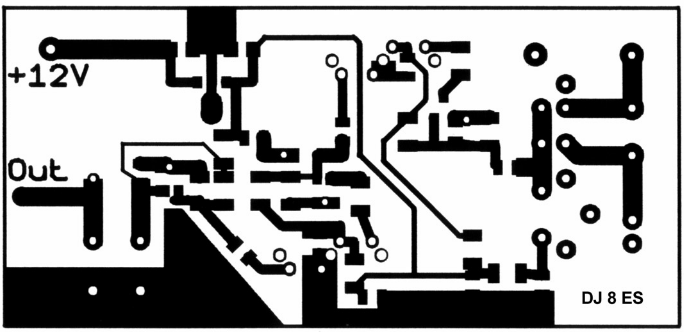

Fig 12: Oscillator printed circuit board, track side DJ8ES-054.

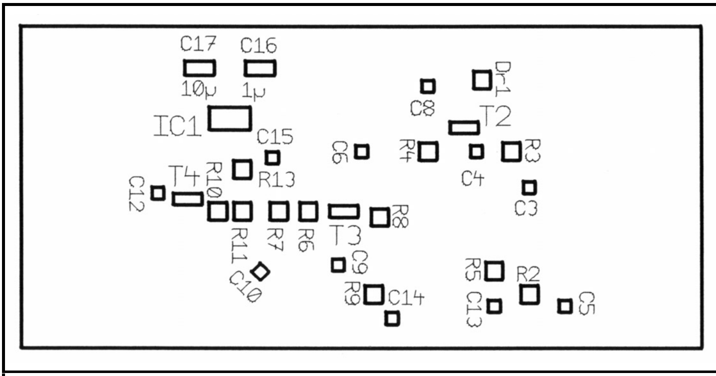

Fig 13: Component layout of oscillator printed circuit board, track side.

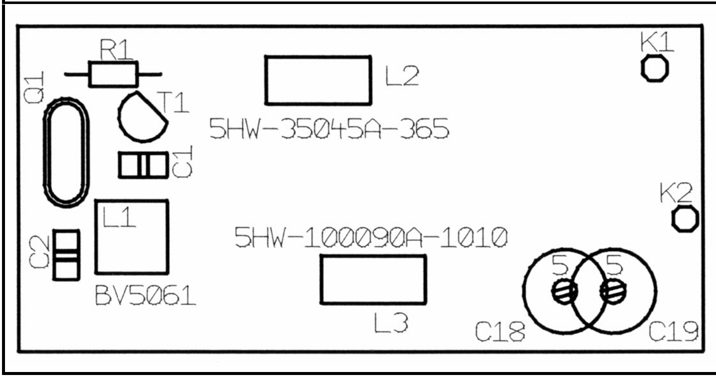

Fig 14: Component layout of oscillator printed circuit board, ground plane side.

drop is measured across resistor R5. As soon as the oscillator starts to, this voltage drop increases rapidly, reaching a maximum value of 3.4V. The optimal setting for the coil core, is slightly below the maximum on the slow rising slope.

Next the tripler (T2, BFR93A) is tuned to 351MHz. To do this, the voltage drop across R9 is used. Using reciprocal tuning of the two circuit helix filter L2, an unambiguous maximum reading (approximately 3.4V) can be obtained. The same applies for the tripler to 1,053MHz. Here the voltage drop across R13 (3.4V) acts as an indicator. This time L3 should be tuned (again reciprocally). The doubler to 2,106MHz should be tuned by

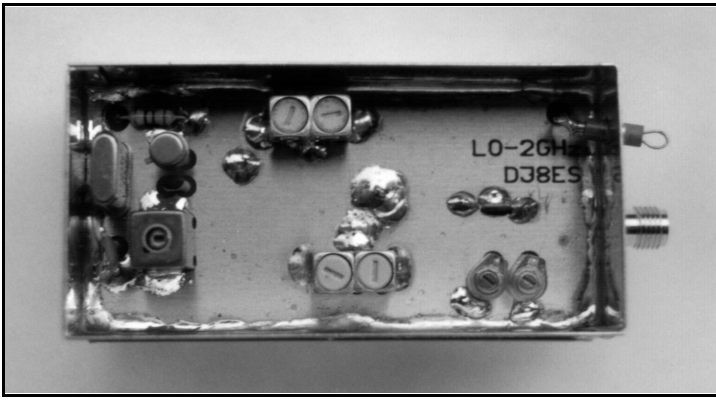

Fig 15: Prototype of the 2106MHz oscillator.

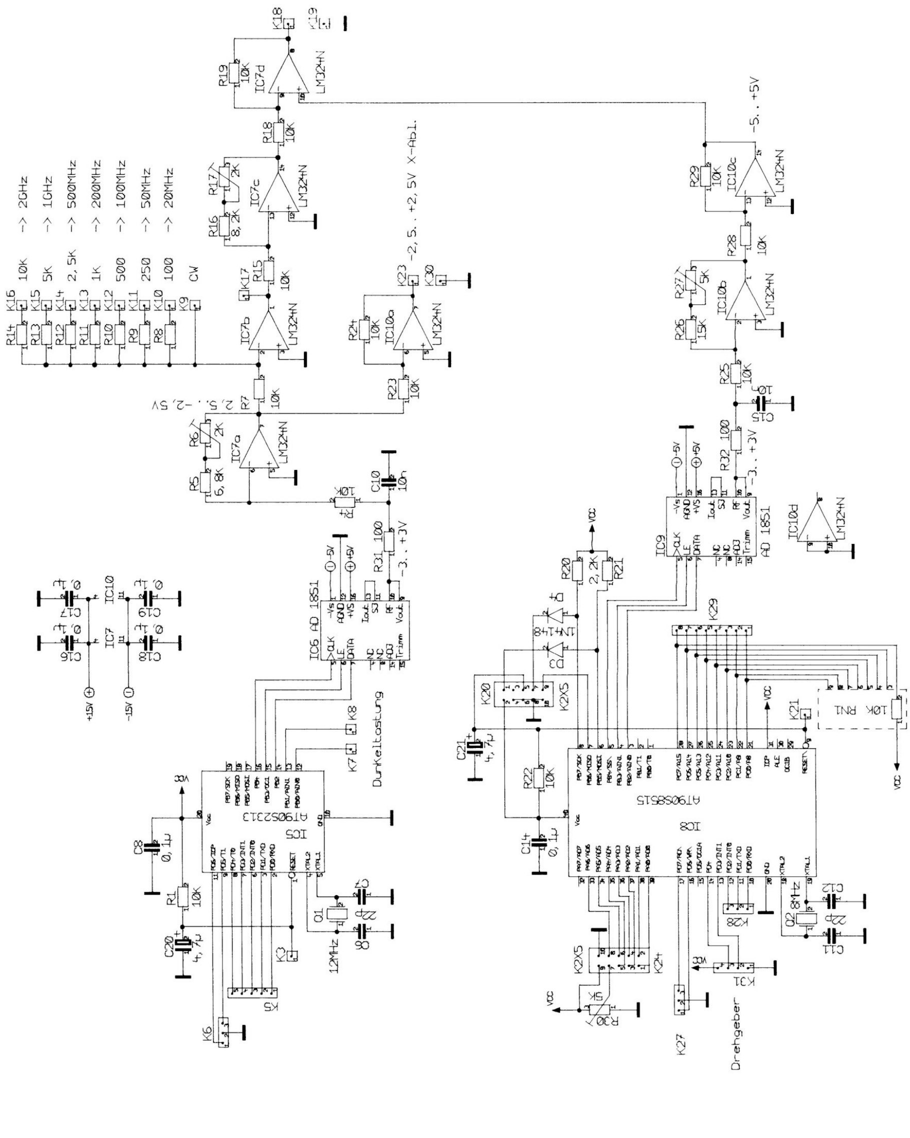

Fig 16: Circuit diagram of micro controller.

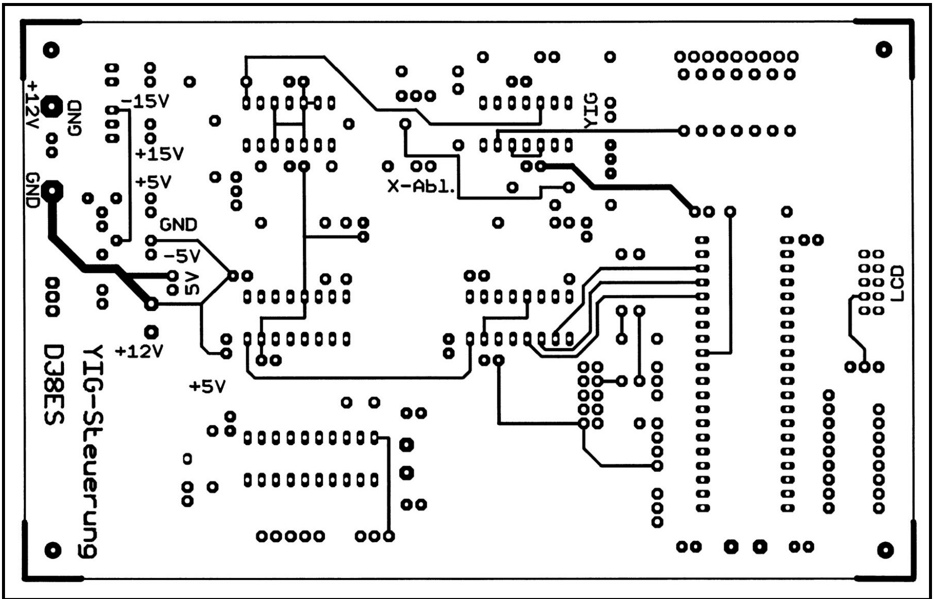

Fig 17: Printed circuit board for micro controller, top side DJ8ES-055.

means of the two 5pF Sky trimmers (C18, C19). Here the output of approximately 2mW should be obtained.

4. Micro controller control

The micro controller circuit (Fig. 16) is divided into two functional parts. A µP AT90S2313 (IC5) micro processor generates the saw form tuning voltage for wobbling. This processor also generates the blanking signal during the flyback on the display. The second micro processor, a µP AT90S8515 (IC8), sets the mean frequency through a shaft encoder and controls the LC display.

The circuit requires a single positive supply voltage of +12V. Other voltages required are generated on the circuit board:

- ±15 V for the operational amplifier with IC1 (NMA1215S),
- ±5 V for the analogue/digital converter with IC2 (78L05) and IC3 (79L05) and
- +5 V for the micro-controller and the LC display with IC4 (7805).

Each micro controller generates a 16 bit digital word that is converted by the digital to analogue converter to give the required voltages for the frequency setting. Downstream amplifiers provide level adjustment to standard values. Thus, for example, the output for the horizontal deflection is defined on a display screen (e.g. oscilloscope) as ±2.5 V. For precise calibration, 3 precision trimming capacitors are provided. In the last operational amplifier, the two analogue signals are combined and used to drive the YIG oscillator.

The amplification of the operational amplifier IC7b can be switched in stages to set the span. The values given for the resistors in the feedback loop allow a span of 2GHz, 1GHz, 500MHz, ... right down to 20MHz. The CW switch posi-

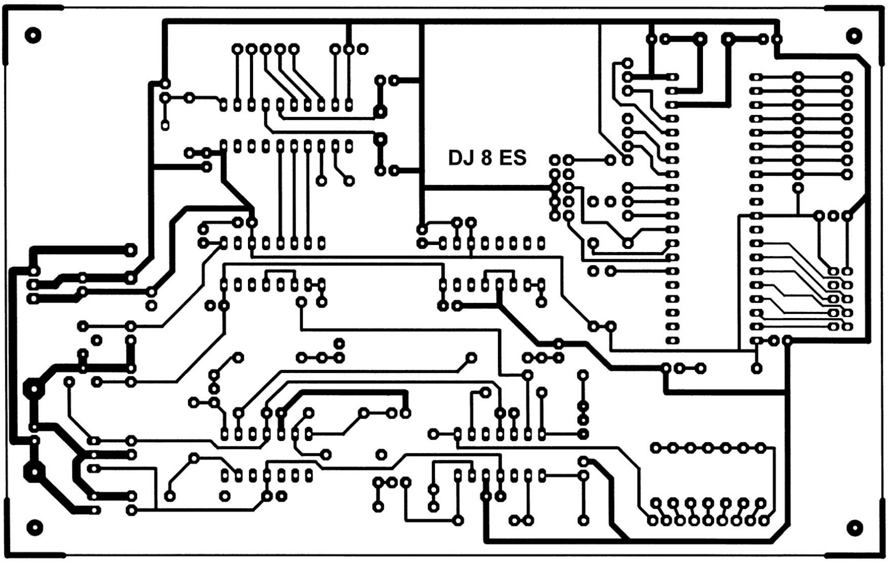

Fig 18: Printed circuit board for micro controller, bottom side.

tion makes standard signal generator operation possible at a frequency that can be set by means of the shaft encoder. The sweep width is not used in this mode. The frequency stability is better than 100kHz over the entire frequency range. Any improvement for genuine narrow band measurements (quartz filters or the like.), can be made using an additional frequency control circuit with a PLL.

To set the wobble speed, 5 connections are taken from IC5 to a socket strip (K5). For faster wobble speeds, one of these connections can be switched to earth. Inverted blanking signals are available for flyback with K7 and K8. K28, pin 1 makes it possible to switch between the upper and lower frequency ranges on the liquid crystal display and pin 3 makes it possible to switch between normal operation and frequency calibration.

For the settings lower frequency range and frequency calibration, the connection pin in question should be switched to earth. Pin 2 is not used in the current software.

4.1. Assembly instructions for micro controller module

The micro controller module occupies a double sided coated epoxy printed circuit board, with the dimensions 100 mm x 160 mm (European standard size pc board) (Figs. 17,18). In contrast to the oscillator assembly, only wired components are used, and no SMD parts are used. The components layout is shown in Fig. 19. The micro processors and A/D converter should be mounted using IC sockets. It is more sensible for all inputs and outputs to use plug connections. The LC display is connected to K24 as per list:

Pin 1: 11, DB4
Pin 2: 12, DB5
Pin 3: 13, DB6
Pin 4: 14, DB7
Pin 5: 6, EN
Pin 6: 4, RS
Pin 7: 3, VEE (LCD drive)
Pin 8: 5, R/W
Pin 9: 2, VDD (+5V)
Pin 10: 1, VSS (GND)

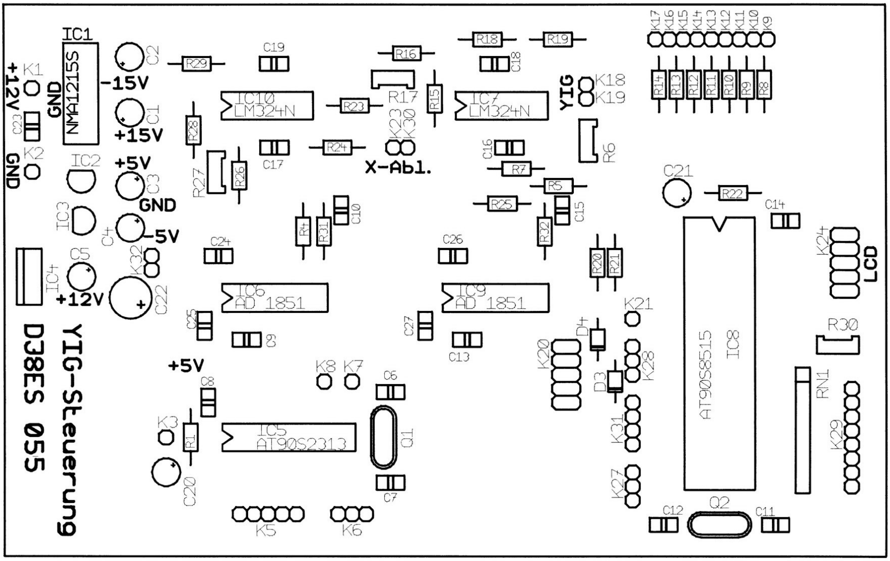

Fig 19: Component layout for micro controller printed circuit board.

The 5kΩ trimming potentiometer (R30) adjusts the contrast of the liquid cryatal display. For illuminated displays, a stabilised +5V voltage is available on K32. The connection usually goes through an external 12Ω resistor.

4.2. Component list for micro controller module

IC1	NMA1215S, voltage converter
IC2	78L05, fixed voltage regulator
IC3	79L05, fixed voltage regulator
IC4	7805, fixed voltage regulator
IC5	AT90S2313-10, micro controller
IC6,IC9	AD1851, D/A converter
IC8	AT90S8515, micro controller
IC7,IC10	LM324, operational amplifier
Q1	Crystal, 12 MHz, HC18-U,
Q2	Crystal, 8 MHz, HC18-U,
R6,R17	2kΩ precision spindle trimmer
R27,R30	5kΩ precision spindle trimmer

Capacitors:

1 x	1000µF, RM 5mm, electrolytic capacitor
5 x	10µF, tantalum electrolytic capacitor
2 x	4.7µF, tantalum electrolytic capacitor
4 x	22pF, RM 2,5 mm, ceramic
2 x	10 nF, RM 2,5 mm, ceramic
13 x	100nF, RM 2,5 mm, ceramic

Resistors, ¼ W, RM 10 mm:

2 x	100Ω
1 x	2.2kΩ
1 x	6.8kΩ
1 x	8.2kΩ
10 x	10kΩ
1 x	15kΩ

Precision resistor, ¼ W, RM 10 mm:

1 x	100Ω
1 x	250Ω
1 x	500Ω
1 x	1kΩ
1 x	2.5kΩ
1 x	5 kΩ

1 x	DJ8ES 055 PCB

4.3. Putting into operation with setup of micro controller module

When the micro controller module is

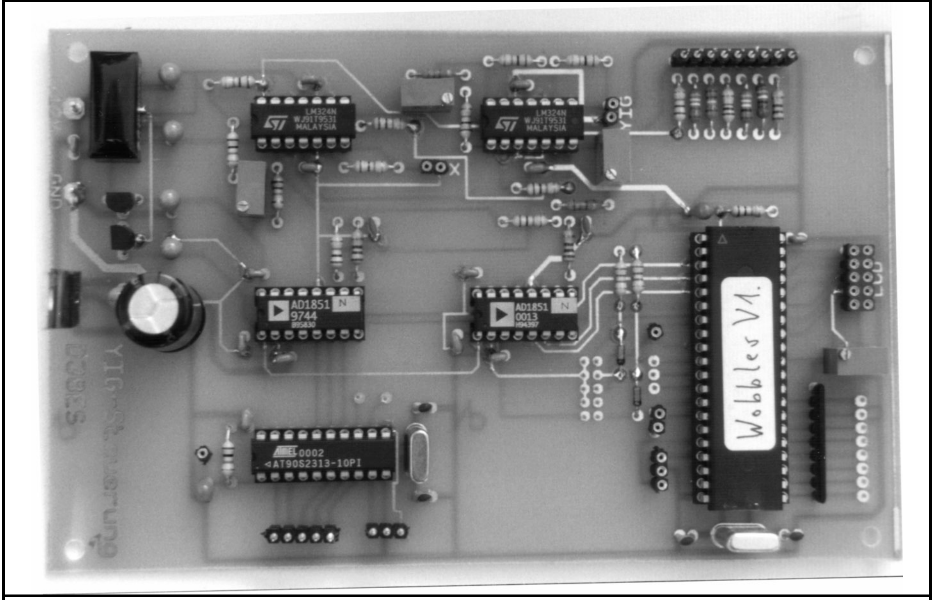

Fig 20: Prototype of micro controller board.

switched on, the tuning voltage generated through the FC AT90S2313 (IC5) starts automatically. The waveform and voltage level can be monitored at connection K23. Positive or negative blanking pulses, each with a pulse length of 10ms, are fed to K7 and K8. A low level at K6/pin 3 is used to switch the micro controller to the lower value. Using potentiometer R6, this minimum value is set to precisely 2.50V. A low level at K3 (Reset) re starts the sawtooth.

A low level at K6/pin 1 is now used to switch the micro controller to the upper value, +2.50V can be monitored at K23. In the event of slight discrepancies in either of these values, the operational voltage, either ±15V for the operational amplifier (IC1, NMA1215S) or ±5V for the analogue/digital converter, is not symmetrical from IC2 (78L05) and IC3 (79L05). In this case, the same voltage level, positive and negative, is set at K23 using R6. The testing and adjustment of the tuning voltage for the mean frequency of 5V to +5V at IC10/pin 14 is carried out in a similar way. This time, the micro controller 90AT8515 (IC8) is switched to the upper or lower maximum value using K27 and calibrated with the precision trimmer R27. The reset connection is available on K21.

To monitor the mean frequency of the YIG oscillator, the sawtooth is switched to CW, i.e. no span, by connecting K9 to K17. The micro controller is switched into calibration mode (K28/pin 3 to earth). Following the reset of the micro controller, the mean frequency is adjusted and programmed. In the prototype, this is the setting value was 22446 for the D/A converter, which corresponds to a frequency of 2,800MHz for the YIG oscillator. 6.85V is now applied at pin 18, or precisely half the voltage, 3.425 V at IC10/pin 14. Fine adjustments can still be made to the frequency using the shaft encoder.

All voltage values are taken from the characteristic of the YIG oscillator shown in Fig. 3. The setting value for the mean frequency is calculated as follows:

Setting value = 32768 * Tuning voltage / 5.0 V / 2
= 32768 * 6.85 V / 50 V / 2
= 22446

To set the span, the shaft encoder remains set to the mean frequency. The span is set to 2GHz (connect K16 with K1). The mean frequencies must be set through the micro controller IC5 and the trimming potentiometer R17; with K6 / pin 3 low minus 1GHz ,and with K6/pin 1 low plus 1GHz , for the mean frequency of the upper maximum frequency. In the specimen apparatus, the following values are valid for this setting:

- 1,800 MHz = 4.55 V
- 2,800 MHz = 6.85 V
- 3,800 MHz = 9.14 V

This gives a voltage range of 9.14V 4.55V = 4.59V for a maximum sweep width of 2GHz. For the final programming of the micro controller IC8 (AT90S8515) by Frank Peter Richter, the settings just obtained are important. The correct display for the frequency can now be programmed for the upper and lower frequency range in the micro controller.

The values for the specimen apparatus are:

- Oscillator frequency: 2,106 MHz
- Mean frequency YIG: 2,800 MHz
- Shaft encoder setting:
  22464 (rounded off, must be divisible by 64)
- Frequency interval per step: 0.13333 MHz per shaft encoder step

If this design is copied using a YIG oscillator which differs considerably from the one in the prototype, then the rate of rise of the tuning voltage and thus the amplification of IC7c must be adjusted, if applicable. This results in a re calculation of resistor R16. In the prototype, the following values apply to this resistor:

R16 = (R15 * dispersion / 5 V) - (R17 / 2)
= (10000Ω * 4.59 V / 5 V) - (2000Ω / 2)
= 8180Ω

Thus for R16 a standard value is selected (E24 series) of 8.2 kΩ.

5. Operational experience and prospects

This frequency generator (wobbler) up to 4GHz has already proved its worth many times both as a test transmitter and as a wobbler (e.g. calibration of band filters) in the VHF/UHF and SHF frequency ranges. The principle of this apparatus is already being used in a further development (spectrum analyser up to 1.8GHz or as slimmed down version up to 500MHz).

Suitable detectors must be used for this frequency. DIY products, even in coaxial formats, can frequently be used only up to frequencies of 2GHz. Beyond this, the input impedance of the detector is far beyond 50Ω and does not allow any reliable measurements to be carried out.

If a standard oscilloscope is used as a display screen, the blanking of the flyback, if applicable, can not be accomplished without modification. One conceivable plan is to short circuit the detector DC voltage with an FET (e.g. BS170) using a small additional circuit. Alternatively, a micro controller with a delta voltage is also available instead of the sawtooth tuning voltage. However, because of the electrical behaviour of the YIG tuning coil due to the back electromotive force, this only works for slow wobble speeds.

At this point, I would like to express my

sincere gratitude to Frank Peter Richter (DL5HAT) for the development of the software and for volunteering to prepare individually programmed micro controllers. In this connection it is conceivable that additional functions could be implemented into the software. Any suggestions along these lines will be particularly welcome.

6. Literature

[1] Bert Kehren, WB5MZJ Microwave components, Proceedings of 45th Weinheim VHF Congress

[2] Michael Kuhne, DB6NT, 13cm linear transverter; DUBUS 3/1993